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WESTERN SPRUCE BUDWORM SUPPRESSION AND
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Santa Fe National Forest and
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Progress Report No. 5
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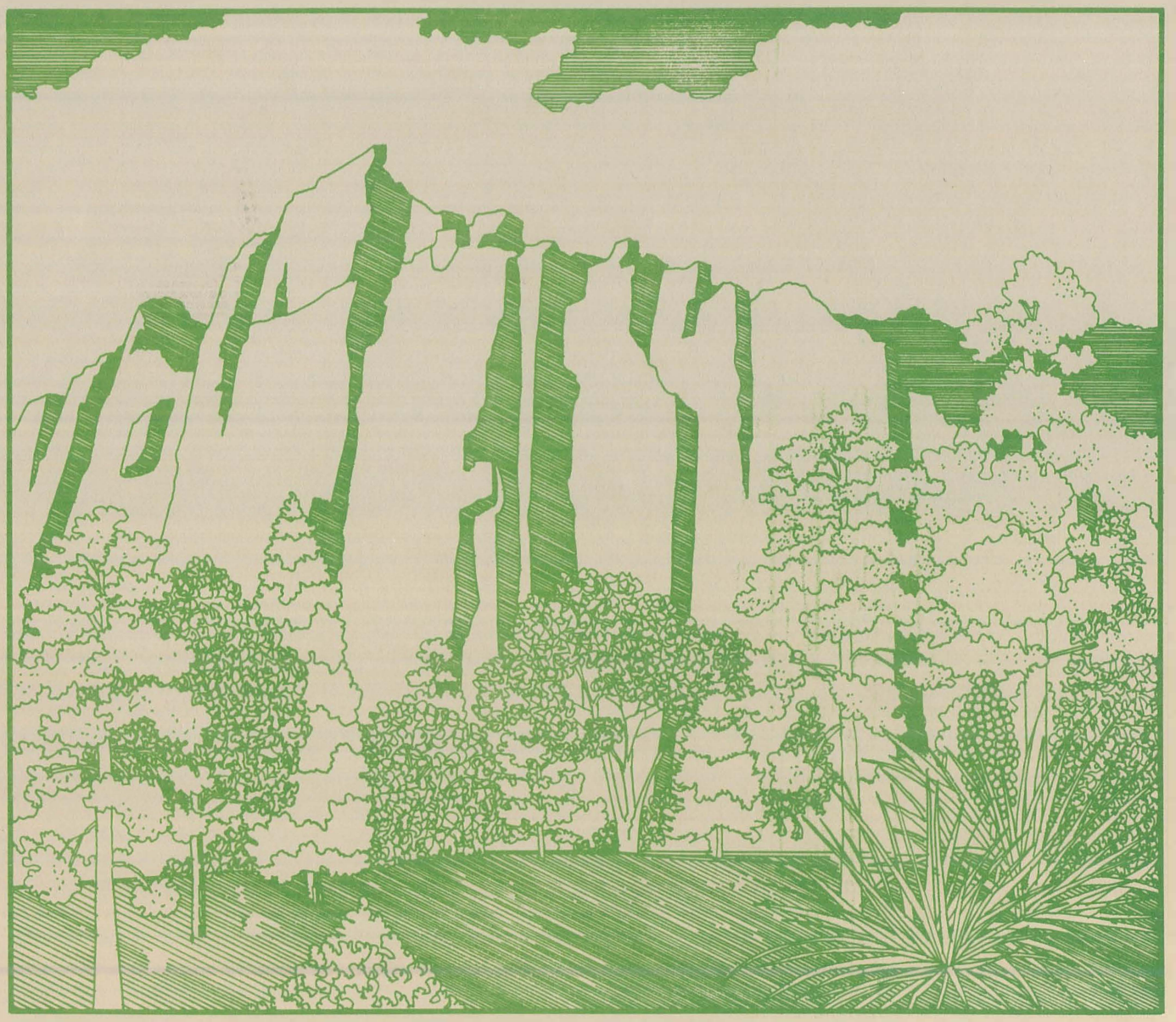

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and
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by

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ABSTRACT

In 1977, carbaryl was aerially applied to an increasing western spruce budworm, Choristoneura occidentalis Free., outbreak in an isolated mountain range in New Mexico. Egg mass density sampling shows that, although budworm population densities are increasing in the treated area, population densities are still low (6.1 egg masses per m^2). Egg mass densities dropped in untreated areas, but the densities are still at a high level (28.8 egg masses per m^2). Percent defoliation increased for the third year on the untreated area and a portion of the treated area. No significant tree damages were recorded on seedlings and saplings. Apparent top-kill of Douglas-fir and true fir poles and sawtimber increased from 1.5 trees per acre in 1977 to 15.4 trees per acre in 1981 in the untreated area.

Egg mass densities and defoliation are expected to continue to increase in treated areas in 1982, but remain at significantly lower levels than in untreated areas. As a result, egg mass densities, defoliation, and tree damages will be sampled again in 1982.

I. INTRODUCTION

In 1977, a suppression project was conducted to evaluate the prolonged effects of an insecticide treatment on a building western spruce budworm, Choristoneura occidentalis Free., outbreak to determine if a "population reduction strategy" was a viable alternative. Sevin® 4 oil was aerially applied to 37,450 acres of forested land in an isolated mountain range on the Santa Fe National Forest and the Jemez Pueblo Indian Reservation. The objectives of the project were to: (1) suppress the budworm population to such a low level that mating becomes less likely, parasites and predators become more significant in regulating the population, and density-independent factors, such as weather, keep the budworm population below an economically damaging level; (2) evaluate the effectiveness of suppression for a 2-year period in the treated area and a comparable untreated check area (37,398 acres); and (3) evaluate and compare annual defoliation and tree damages in the treated and untreated areas.

The application phase of the project was successfully completed in 1977 (Parker et al. 1978).[1/] Criteria established to show treatment success were: (1) reducing the budworm larval density by an average of 90 percent and (2) obtaining an egg mass density of less than 1.5 new egg masses per square meter of foliage. The 1976-77 budworm generation was reduced by an average of 93.1 percent, compared with a 44.5 percent reduction in the untreated area. The adjusted budworm mortality, using Abbott's formula, was 87.5 percent. One larva per 100 buds of Douglas-fir remained 14 days following treatment. The average density of new egg masses was 1.6 per square meter in the treated area and 9.9 per square meter in the untreated area. Although an average of 84.1 percent of the budworm larvae were in the fifth and sixth instars and 0.3 percent were pupae at the time of treatment; defoliation was considerably lower than that recorded in the untreated area: treatment area--26.5 percent for Douglas-fir and 37.0 percent for white fir; untreated area--40.8 percent for Douglas-fir and 61.3 percent for white fir.

Sampling for larval densities, number of egg masses, and defoliation on the plots was done in 1978 and 1979 to determine whether suppression effects continued. Larval and egg mass densities and defoliation all remained at low levels for both years in the treated areas, and increased in the untreated area.[2/ 3/]

1/ Parker, Douglas L., Robert E. Acciavatti, and Eugene D. Lessard. 1978. Western spruce budworm suppression and evaluation project using carbaryl. Progress Rep. No. 1, USDA Forest Serv., Southwestern Reg., Albuquerque, NM. R-3 78-11. 136 pp.

2/ Parker, Douglas L., Eugene D. Lessard, and Iral Ragenovich. 1979. Western spruce budworm suppression and evaluation project using carbaryl. Progress Rep. No. 2, USDA Forest Serv., Southwestern Reg., Albuquerque, NM. R-3 79-8. 109 pp.

3/ Parker, Douglas L., and Iral R. Ragenovich. 1980. Western spruce budworm suppression and evaluation project using carbaryl. Progress Rep. No. 3, USDA Forest Serv., Southwestern Reg., Albuquerque, NM. R-3 80-1. 56 pp.

Sampling for egg mass densities, defoliation, and mortality and top-kill of seedlings and saplings was done in 1980.[4/] Egg mass densities and defoliation remained at low levels in the treated areas and continued to increase in the untreated areas. In 1981, egg mass density, defoliation, and mortality and top-kill of both seedlings and saplings and poles and sawtimber were sampled. Results are presented in this report.

II. METHODS

A. Sampling Locations

The treated and untreated areas were divided into six subunits in 1977 (figure 1). In each subunit, 25 permanent plots (3-tree cluster) were established, as uniformly as possible, throughout each subunit along roads and trails. Each plot was assigned a unique number. Data were collected on these permanent plots from 1977 to 1979. In 1980, 12 of the original 25 permanent plots in each subunit were used for data collection. The same 12 subunits were used again for sampling in 1981.

B. Egg Mass Densities

1. Sampling Design for Egg Masses

In late July, two branches (70 cm in length) were cut from opposite sides of sample trees on permanent plots. The length and width of each branch were used to calculate foliated branch area.

Foliage from all branches was examined under ultraviolet light for egg masses. Needles bearing egg masses were classed as from current year's foliage, or a previous year, and kept separate in labeled pill boxes. New and old egg masses were separated under a stereomicroscope. All egg masses on current year's foliage were classed as new, and their characteristics formed the basis for aging those egg masses found on the previous year's foliage.

2. Analysis of Egg Mass Density Levels

Egg mass densities were expressed as number of new egg masses per square meter (1,550 square inches) of foliage. Subunit and treatment level means and standard errors were computed by the following equations.

4/ Ragenovich, I. R., and D. L. Parker. 1981. Western spruce budworm suppression and evaluation project using carbaryl, 1980. Progress Rep. No. 4, USDA Forest Serv., Southwestern Reg. R-3 81-9. 43 pp.

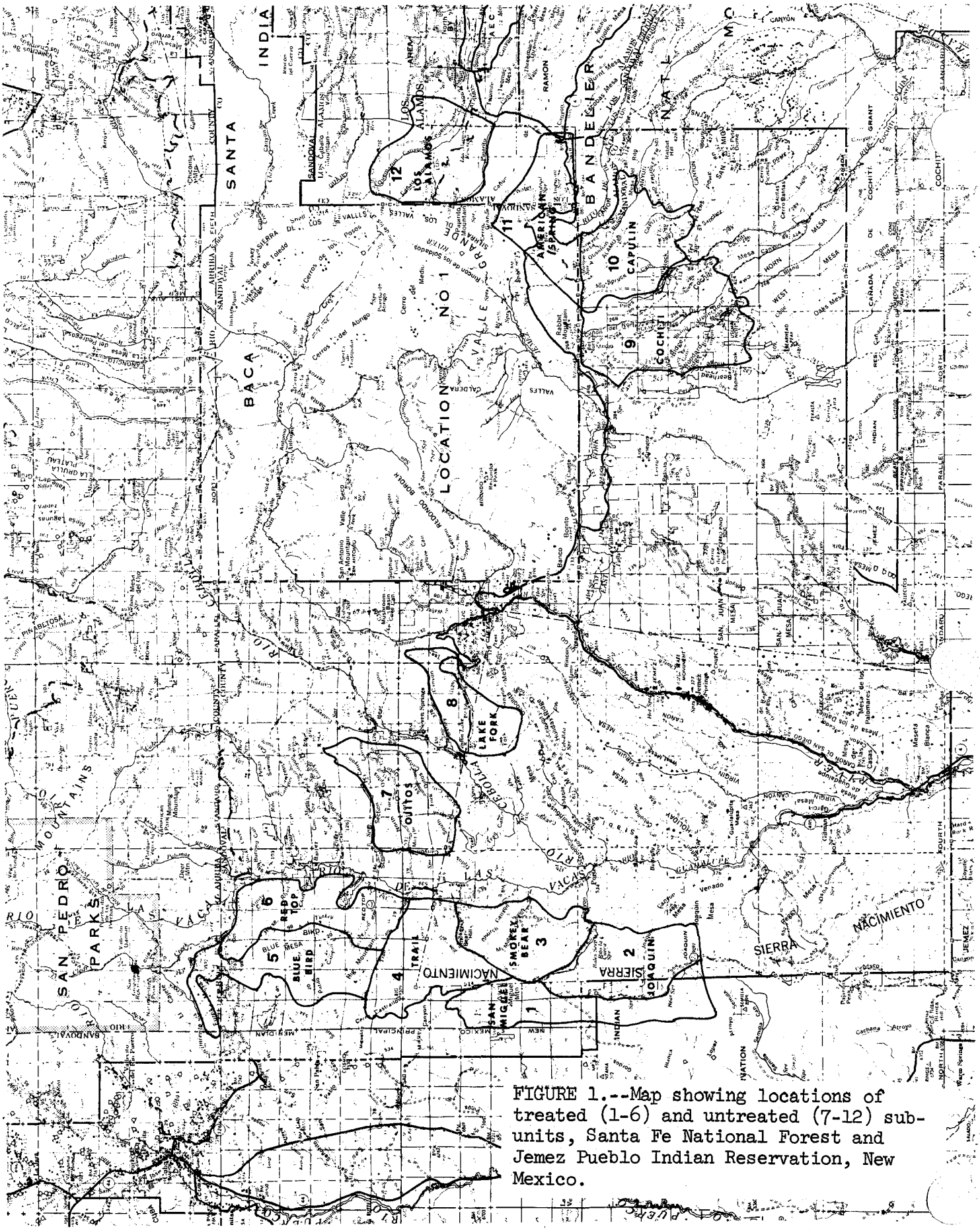

FIGURE 1.--Map showing locations of treated (1-6) and untreated (7-12) sub-units, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

a. Subscripts:

i = treatments	1 = spray, 2 = check
j = subunits	j = 1, 6
k = cluster	k = 1, 12
l = tree	l = 1, 3
m = branch	m = 1, 2

b. Cluster level:

$$X_{ijk} = \frac{\sum_{l=1}^{3} \sum_{m=1}^{2} \frac{\text{egg masses}_{ijklm}}{M^2 \text{ foliage}_{ijklm}}}{6}$$

where X_{ijk} is the mean for the k^{th} cluster in the j^{th} subunit in the i^{th} treatment.

c. Subunit level:

$$X_{ij} = \frac{\sum_{k=1}^{n} X_{ijk}}{}$$

where X_{ij} is the mean for the j^{th} subunit in the i^{th} treatment.

$$\text{S.E. } x_{ij} = \sqrt{\frac{\sum_{k=1}^{n} X_{ijk}^2 - \left(\frac{\sum_{j=1}^{n} X_{ijk}}{n}\right)^2}{n-1}}$$

where S.E. X_{ij} is the standard error of the mean X_{ij}.

d. Treatment level:

$$X_i = \frac{\sum_{j=1}^{6} X_{ij}}{6}$$

where X_i is the mean for the i^{th} treatment.

$$S.E.\ X_i = \sum_{j=1}^{6} S.E.\ X_{ij}^2$$

where S.E. X_i is the standard error of the mean X_i.

C. Percent Defoliation

Defoliation on Douglas-fir was sampled on 12 clusters in each subunit. On all clusters, 3 codominant Douglas-fir, 30 to 50 feet tall, with relatively open-grown crowns, were sampled.

Sample branches consisted of 4 apical branches, 70 cm in length, taken from 4 quadrants at midcrown of each sample tree. From each of these branch samples, 25 new shoots were examined for current defoliation using the left side of 1 branch and the right side of another, and so on. Each new shoot was individually examined for defoliation and assigned an index value as follows:

6-class

Defoliation class %	Index value	Midpoint value %
0	0	0
1-25	1	12.5
26-50	2	37.5
51-75	3	62.5
76-99	4	87.5
100	5	100

Defoliation estimates were analyzed on a "per cluster" basis.

The following formula was used to determine the percent defoliation on a "per cluster" basis.

$$\text{Percent defoliation} = \frac{n_1\ (12.5) + n_2\ (37.5) + n_3\ (62.5) + n_4\ (87.5) + n_5\ (100)}{N}$$

where n_1 = number of twiglets with index value 1
n_2 = number of twiglets with index value 2
n_3 = number of twiglets with index value 3
n_4 = number of twiglets with index value 4
n_5 = number of twiglets with index value 5

The previous formulas that were used to calculate egg mass densities by cluster, subunit, and treatment were used to calculate percent defoliation by cluster, subunit, and treatment.

D. Tree Mortality and Top-kill

1. Poles and Sawtimber

Tree damages on poles and sawtimber were not collected in 1980, but sampling was done in 1981. Data were collected by using variable plots (20 BAF) at the center subplot of each cluster plots. Apparent top-kill was determined visually. A tree was determined to be top-killed if there was no green foliage and no visible buds. The stem appeared to be recently dead, and not just defoliated. Two crew members had to agree the tree was top-killed before it was recorded as such.

2. Seedlings and Saplings

Tree damage data were collected at 5 locations in each of the treated and untreated subunits, for a total of 60 sample locations. At each location, a cluster of five permanent 1/100-acre fixed radius plots were sampled. Permanent 1/100-acre plots established in 1977 were used as the center plot, and 4 additional plots were located 100 feet from the center of the permanent plot in cardinal directions. Trees were recorded by species and condition (live, top-killed, dead). Trees with a diameter at breast height (d.b.h.) of less than 0.5 inches or less than 4.5 feet in height were considered seedlings. Saplings are 0.5 to 4.9 inches d.b.h. Pine and spruce trees also were recorded on each plot. Data were analyzed using the PEST computer program.5/

III. RESULTS

A. Egg Mass Densities

Average egg mass densities on the treated and untreated subunits are shown in table 1. In the treatment area, average egg masses per square meter of foliage decreased from 1.7 in 1977 to 0.4 in 1978, increased slightly to 0.6 in 1979, increased to 4.9 in 1980 and 6.1 in 1981. Average egg masses per square meter of foliage in the untreated areas were: 1977, 9.9; 1978, 10.1; 1979, 15.9; 1980, 48.0; and 1981, 28.8 (figure 2). Average egg mass densities have increased in the treated areas, thus defoliation is expected to be greater in 1982. Although the average density of egg masses decreased in untreated areas in 1981, heavy defoliation is still expected since the average egg mass density, 28.8, is still at high population levels.

5/ Acciavatti, R. E., and B. W. Geils. 1977. A user's guide to "PEST": A computer program for summarizing forest insect and disease damage surveys. USDA Forest Serv., Southwestern Reg., Albuquerque, NM. R-3 77-16. 45 pp.

TABLE 1.--Western spruce budworm egg mass densities on treated (1-6) and untreated (7-12) check subunits, Santa Fe National Forest and Jemez Pueblo Indian Reservation lands, New Mexico

Treated subunits	Egg masses per m^2 of foliage									
	1977		1978		1979		1980		1981	
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.
1. San Miguel	4.2	1.1	0.9	0.3	0.7	0.3	3.4	1.1	4.4	1.6
2. Joaquin	1.4	0.5	0.0	0.0	0.2	0.1	6.4	1.8	5.9	1.2
3. Smokey Bear	0.2	0.1	0.2	0.1	0.4	0.2	3.5	0.7	3.9	0.9
4. Trail	1.9	0.6	0.6	0.2	1.2	0.4	7.6	4.0	5.4	2.4
5. Blue Bird	1.2.	0.4	0.4	0.2	0.8	0.3	5.7	4.7	4.6	1.5
6. Red Top	1.0	0.3	0.5	0.2	0.6	0.3	2.8	0.7	12.4	3.1
Average	1.7		0.4		0.6		4.9		6.1	
Untreated subunits										
7. Ojitos	1.0	0.3	1.0	0.3	1.5	0.6	14.9	6.0	14.1	2.6
8. Lake Fork	7.5	1.7	11.2	2.6	17.9	3.7	39.6	11.0	37.2	7.7
9. Cochiti	11.6	2.9	12.4	2.5	21.0	5.2	69.7	9.0	37.4	7.8
10. Capulin	14.4	2.5	12.5	1.9	19.2	3.3	51.7	9.2	32.6	5.4
11. American Springs	7.4	1.1	11.1	1.7	15.0	2.8	60.1	8.9	22.4	3.1
12. Los Alamos	17.5	2.6	12.5	1.9	20.6	3.2	51.9	6.6	29.1	3.7
Average	9.9		10.1		15.9		48.0		28.8	

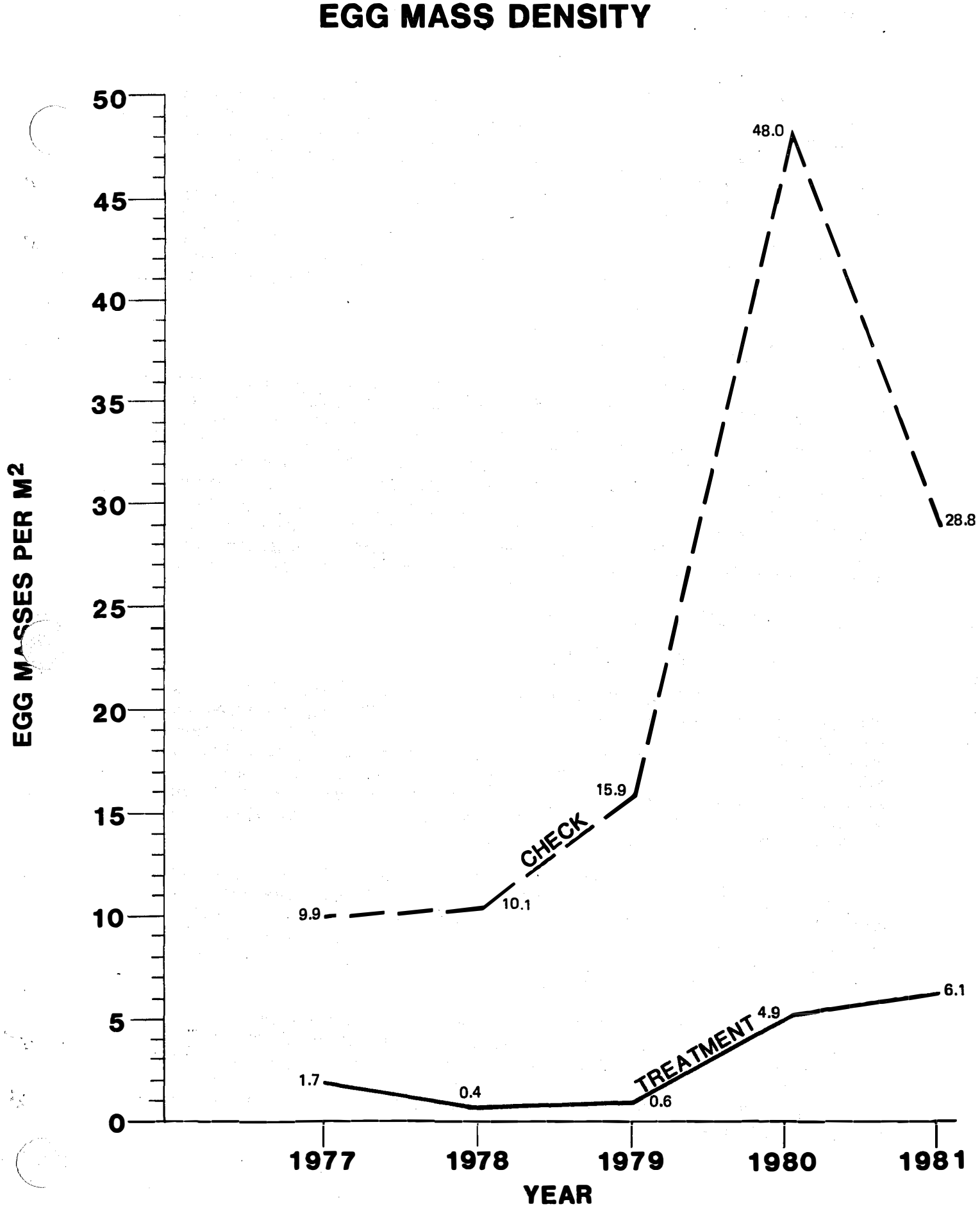

Figure 2. Comparison of average number of western spruce budworm egg masses in treated and untreated check areas, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

Egg mass densities increased substantially on all treated and untreated subunits in 1980. In 1981, egg mass densities appear to have dropped in the untreated areas and increased in the treated areas. Egg mass densities may have dropped in the untreated areas because of a lack of suitable foliage for deposition. The increase in egg mass densities in the treated area is primarily due to a large increase in the Red Top subunit, table 1. The Red Top subunit had little defoliation detectable by aerial detection surveys in 1981; however, adjacent untreated areas have been heavily defoliated, figure 3. Thus, the increase in the Red Top subunit may be invasion from adjacent heavily defoliated areas.

B. Percent Defoliation

Average percent defoliation in treated areas increased from 9.6 in 1980 to 31.9 in 1981, and increased in untreated areas from 54.7 in 1980 to 67.2 in 1981. A comparison of defoliation between treated and untreated areas shows that foliage protection was still being achieved in the treated area in 1981 (table 2, figure 4), but less so than in previous years. Percent defoliation in treated areas increased as a result of the greater budworm populations resulting from the increase in egg masses that occurred in 1980. Defoliation, as measured in this report, and as detected by aerial detection surveys, is expected to increase in both treated and untreated areas.

C. Tree Mortality and Top-kill

1. Pole and Sawtimber

Mortality and apparent top-kill of budworm host trees measured in 1981 are shown in table 3. Top-kill was recorded as apparent top-kill since this is the first year top-kill has been measured, and was judged by visual inspection of the standing trees. Apparent top-kill is most likely greater than actual top-kill. Douglas-fir apparent top-kill is greater in the untreated area (19.28 percent of the trees, by trees per acre) than in the treated area (1.68 percent of the trees, by trees per acre).

Table 4 compares the combined Douglas-fir and true fir apparent top-kill measured in 1981 with the 1977 base line data for combined Douglas-fir and true fir apparent top-kill. It appears that the carbaryl spray in 1977, which successfully lowered budworm population densities and the resulting defoliation for 5 years, also prevented budworm induced apparent top-kill.

Average diameters of apparent top-killed Douglas-fir and true fir were 12.7 and 9.4 inches, whereas average diameters of Douglas-fir and true fir that had been defoliated, but are without apparent top-kill, were 14.8 and 13.6 inches. This indicates that the less vigorous, inferior crown-class trees are more susceptible to damage by the budworm.

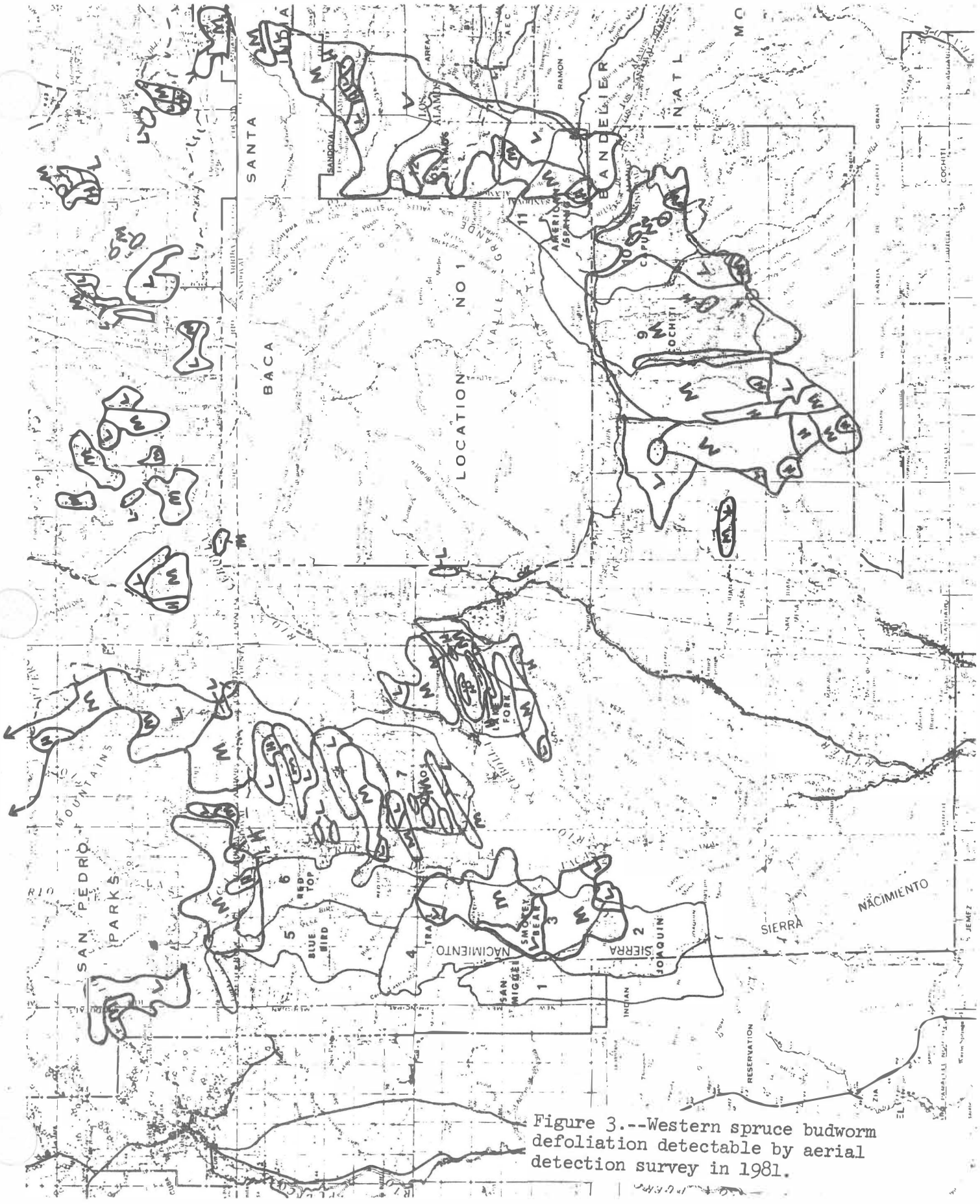

Figure 3.--Western spruce budworm defoliation detectable by aerial detection survey in 1981.

TABLE 2.--Percent defoliation of Douglas-fir treated (1-6) and untreated subunits, Santa Fe National Forest and Jemez Pueblo Indian Reservation lands, New Mexico

Subunits	Percent defoliation				
Treated	1977	1978	1979	1980	1981
1. San Miguel	41.6	4.5	3.7	9.2	25.5
2. Joaquin	19.9	1.5	2.0	7.1	51.9
3. Smokey Bear	18.0	1.1	1.0	7.6	31.5
4. Trail	37.0	5.4	2.2	12.5	25.3
5. Blue Bird	25.5	2.7	3.0	13.6	23.6
6. Red Top	16.6	2.0	3.2	8.1	33.6
Average	26.5	2.9	2.5	9.6	31.9
Untreated					
7. Ojitos	14.1	9.4	6.8	24.4	65.0
8. Lake Fork	51.1	40.9	34.1	48.4	72.6
9. Cochiti	37.2	35.3	29.4	55.4	71.8
10. Capulin	51.2	29.0	28.3	65.7	61.0
11. American Springs	34.2	29.1	31.6	73.5	65.4
12. Los Alamos	56.7	23.8	29.9	60.9	67.2
Average	40.8	27.9	26.7	54.7	67.2

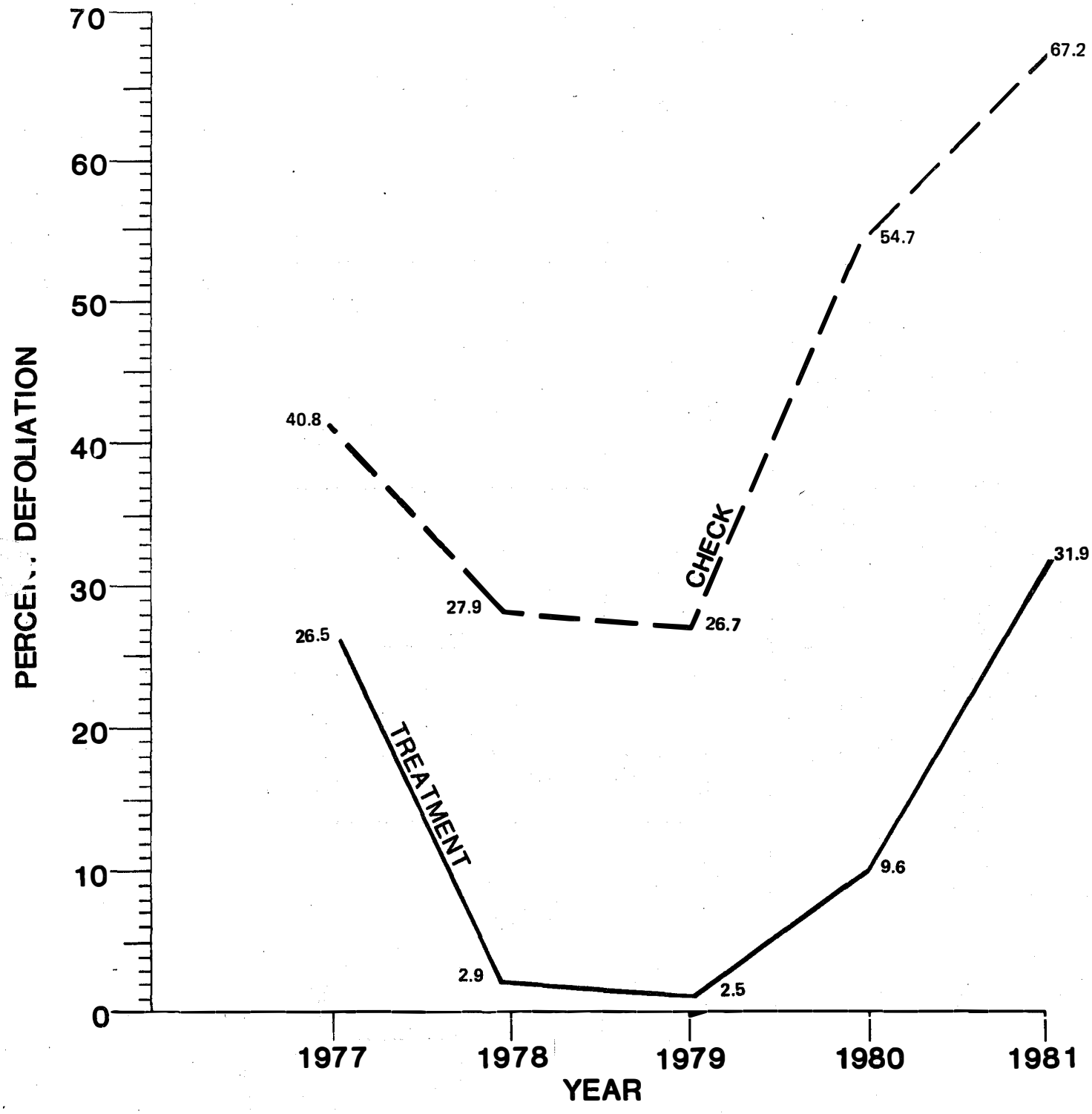

Figure 4 Comparison of average western spruce budworm-caused defoliation of Douglas-fir in treated and untreated check areas, Santa Fe National Forest and Jemez Pueblo Indian Reservation, New Mexico.

TABLE 3.--1981 budworm host-tree pole and sawtimber mortality and apparent top-kill by trees per acre, basal area, and average diameters

	Treated			Untreated		
	Trees per acre	Basal area	Average diameter	Trees per acre	Basal area	Average diameter
Douglas-fir						
Live	105.8 ± 0.19[1/]	51.4 ± 0.61	11.0	58.6 ± 0.12	32.7 ± 0.56	14.8
Dead	0	0	---	0	0	---
Top-kill	1.8 ± 0.18	0.7 ± 0.67	8.2	14.0 ± 0.83	8.0 ± 0.39	12.7
Total	107.6	52.1		72.6	40.7	
True fir						
Live	32.8 ± 0.94	22.7 ± 0.53	13.4	33.9 ± 0.11	19.4	13.6
Dead	0.4 ± 0.41	0.7 ± 0.67	17.2	0	0	---
Top-kill	4.6 ± 0.36	1.4 ± 0.93	8.2	1.4 ± 0.15	0.7 ± 0.7	9.4
Total	37.8	24.8		35.3	20.1	
Total host trees						
Live	138.6	74.1		92.5	52.1	
Dead	0.4	0.7		0	0	
Top-kill	6.4	2.1		15.4	8.7	
Total	145.4	76.9		107.9	60.7	

1/ Standard error.

TABLE 4.--Comparison of base line data for 1977 and 1981 trees per acre of combined Douglas-fir and true fir pole and sawtimber top-kill

Douglas-fir and true fir top-kill			
Trees per acre			
	1977	1981	Increase
Treated	4.56	6.46	1.90
Untreated	1.51	15.41	13.90

2. Seedlings and Saplings

Mortality and top-kill of budworm host trees measured in 1981 are shown in table 5. Percent mortality and top-kill of Douglas-fir, true fir, and combined, on a trees per acre basis, are shown in table 6. Although not directly comparable with the 1977 base line data, the 1981 data indicate that there has been no significant impact on the seedlings and saplings through the sixth year of the infestation.

IV. SUMMARY

Results of the 1981 sampling show that treatment of a western spruce budworm infestation early in the outbreak cycle can keep population levels low for up to 5 years. Also, apparent top-kill of poles and sawtimber appear to be prevented as long as population levels remain low due to treatment early in the outbreak cycle.

Budworm populations in treated areas are currently at levels sufficient to cause perceptible defoliation. Population increases may be due to resident population buildup, immigration from infested adjacent untreated areas, or a combination of both.

V. FUTURE PLANS

Since population levels in treated and untreated areas are still significantly different, egg mass density, defoliation, and tree damages will be measured in 1982. In addition, tree damages will be sampled periodically in future years to assess the long-term impact of a treatment performed early in a spruce budworm infestation.

TABLE 5.--1981 budworm host-tree seedling and sapling mortality and top-kill by trees per acre and average diameters

	Treated		Untreated	
	Trees per acre	Average diameter	Trees per acre	Average diameter
Douglas-fir				
Live	151.1 ± 0.21[1/]	1.38	258.0 ± 0.27	1.31
Dead	5.9 ± 0.21	1.56	3.3 ± 0.17	1.26
Top-kill	9.6 ± 0.25	1.24	23.3 ± 0.61	1.27
Total	166.6		284.6	
True fir				
Live	175.5 ± 0.34	1.68	530.0 ± 0.13	0.92
Dead	8.1 ± 0.32	1.35	14.7 ± 0.46	0.75
Top-kill	19.2 ± 0.73	1.54	39.3 ± 0.74	1.28
Total	202.97		584.01	
Total host trees				
Live	326.6		788.0	
Dead	14.1		18.0	
Top-kill	28.9		62.7	
Total	369.6		868.67	

1/ Standard error.

TABLE 6.--Percent mortality and top-kill of seedling and sapling Douglas-fir, true fir, and combined host trees on a trees per acre basis

	Treated	Untreated
Mortality		
Douglas-fir	5.78	8.20
True fir	9.49	6.74
Total	7.82	7.21
Top-kill		
Douglas-fir	3.56	1.17
True fir	4.02	2.51
Total	3.81	2.07